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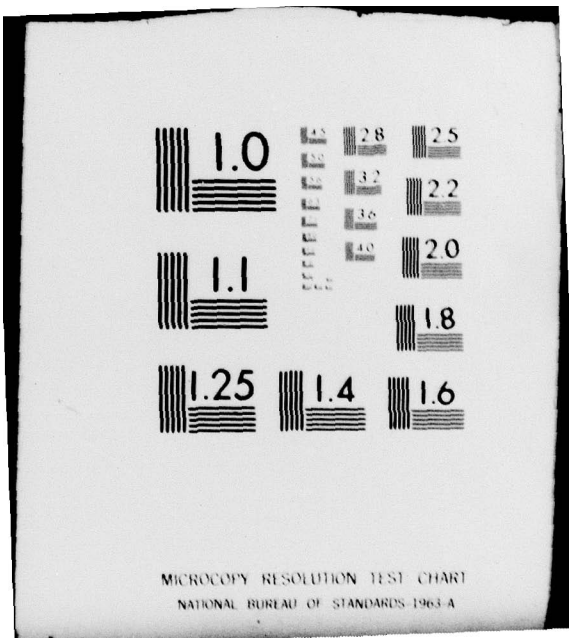
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ANNUAL SUMMARY OF MOLECULAR BEAM STUDIES OF LOW ENERGY REACTIONS

ONR CONTRACT NO. N00014-74-C-0011

PRINCIPAL INVESTIGATOR: R. H. NEYNABER

October 15, 1979

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Ion-molecule reactions
Cross sections
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The annual summary of the research performed under ONR Contract No. N00014-74-C-0011 is given. The report describes merging and crossed-beam studies of chemi-ionization and/or ion-molecule reactions. Included are investigations of the He^*-D, Ne^*-Xe, Ar^*-Kr^*, Ne^*-Ar^*, He^+-Ne^*, and Kr^+-Cs systems. A description is also given of how this research helps resolve unknown aspects of the areas investigated.

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Annual Summary

of

Molecular Beam Studies of Low Energy Reactions

ONR Contract No. N00014-74-C-0011

1. Contract Description

Chemi-ionization and ion-molecule reactions involving metastable and ground-state atoms are studied by both crossed and merging beams at low relative energies (i.e., 0.01 to 10 or 20 eV).

2. Scientific Problem

Some theories exist for chemi-ionization involving collisions of metastable and ground-state rare gases. There is very little experimental data to test these theories over a range of relative kinetic energy from 0.01 to 10 or 20 eV. We will supply such data. Theoretical work for collisions between two metastables is almost non-existent, and experimental data is scant. We will supply experimental information such as absolute and relative cross sections and branching ratios for associative to Penning ionization. This information should establish patterns to test those calculations that do exist and will stimulate further theory. Our chemi-ionization data also will produce some information on unknown potentials for the systems A^*B and C^*D^*, where A, B, C, and D are atoms and asterisks denote metastables. This information includes well depths and the dependence of the long range potential on internuclear separation.

The composition of keV neutral rare gas beams formed by charge transfer of the rare gas parent ion beam in alkalis is unknown. The beams consist of rare gas metastables (generally in two states) and ground-state atoms. The technique for generating such beams is common, and information on the composition is needed in analyzing data obtained through their use. We have developed a method for obtaining the fraction of ground-state atoms in such beams by studying appropriate ion-molecule reactions. We will apply this method to determine unknown compositions.

No experimental information exists on low-energy resonant or near-resonant charge-transfer reactions between rare gas ions and metastables. Our experiments will supply such information. The data can be used to see if existing theories for charge transfer between ions and ground-state atoms can be extended to this case. We also will investigate energy distributions of product ions from which information on the reaction kinetics can be obtained.

3. Scientific and Technical Approach

Merging-beams techniques will be used for most of the studies. The two reactants of the process under investigation will be merged. Their velocities will be adjusted with respect to each other so that the desired relative energy in the center-of-mass system will be obtained. Product ions resulting from the reaction will be collected to give relative and absolute cross sections, and branching ratios will be obtained when appropriate.

Some crossed-beams measurements will be made of the ion-molecule reactions at relative energies above 1 eV. Again product ions will be measured to obtain cross sections.

4. Progress

We have made the following progress during the post contract period.

a) Our results for charge transfer in the He^+-Ne^* system have been published as have our chemi-ionization studies in the He^*-D system.

b) Chemi-ionization studies of the Ne^*-Xe system have been conducted. Comparisons are made with our data for the Ne^*-Ar and Ne^*-Kr systems. Absolute cross sections are compared with those obtained by others using beam and flowing-afterglow techniques.

c) We have determined the fraction of ground-state atoms in composite krypton beams generated by charge transfer of Kr^+ in Cs at ion energies of 3500, 4500, and 5500 eV. The results were published.

d) Absolute and relative cross sections were determined for chemi-ionization in the Ar^*-Kr^* system. A total ionization cross section of 308×10^{-16} cm^2 was measured at a relative kinetic energy of 0.033 eV. The well depth of the potential curve of Ar^*-Kr^* was determined to be a few tenths of an electron volts.

e) Chemi-ionization in the Ne^*-Ar^* system has been studied including the Penning ionization reactions A) $Ne^* + Ar^* \rightarrow Ne + Ar^+ + e$ and B) $Ne^* + Ar^* \rightarrow Ne^+ + Ar + e$. Laboratory-energy distributions of Ar^+ and Ne^+ from Reactions A) and B), respectively, as well as relative cross sections for these two processes indicate that either the molecular states of the reactants or of the products of the reactions are different.

5. Publications

a) S. Y. Tang and R. H. Neynaber, "Charge Transfer between Helium Ions and Metastable Neon," Phys. Rev. A18, 1925 (1978).

b) R. H. Neynaber and S. Y. Tang, "Penning and Associative Ionization in the Metastable Helium-Atomic Deuterium System," J. Chem. Phys. 69, 4851 (1978).

c) R. H. Neynaber and S. Y. Tang, "Chemi-ionization in Collisions of Metastable Neon with Xenon," J. Chem. Phys. 70, 4272 (1979).

d) R. H. Neynaber and S. Y. Tang, "Composition of Partially Metastable Kr Beams," Chem. Phys. Lett. 65, 150 (1979).

6. Extenuating Circumstances

None.

7. We do not expect any unspent funds remaining at the end of the current contract period.

8-9. No graduate students or postdoctoral personnel have been associated with the contract.

10. R. H. Neynaber also gets partial support from the Air Force Office of Scientific Research, Contract No. F49620-78-C-0015.